Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Common Carrier Bureau Seeks	)	CC Docket No. 96-45
Comment on Requests to	)	
Redefine "Voice Grade Access"	)	
For Purposes of Federal	)	
Universal Service Support	)	

Exparte Comments of the
Rural Utilities Service

Introduction

The Rural Utilities Service (RUS) is a rural development agency of the United States Department of Agriculture. For over 50 years, RUS (originally the Rural Electrification Administration) has been helping build modern telecommunications systems in rural America. Today, RUS continues to promote rural telecommunications by providing financing and technical advice to about 825 rural local exchange carriers.

In reply comments in this proceeding on behalf of the United States Telephone Association, exception was taken to the RUS' position on changing the definition of voice grade access. Because we had no opportunity to respond to these comments during the reply period, we wish to clarify our position through this exparte filing.

RUS comments concerning the definition of voice grade access focus on the future, not the past. The definition of voice grade service will be a defacto standard for newly constructed plant, whether it is in an unserved location or in an existing territory that is rebuilt or overbuilt because of the ravages of time or because a carrier seeks to provide better service. As such, RUS believes the definition should promote the Act's vision of an evolving level of service and its promise of comparability of service in rural and non-rural areas. Universal service support should not be utilized to construct new barriers to the broadband world of the future.

Specifically, RUS wishes to address comments made concerning the Federal Communications Commission's (Commission's) procedure, improved data rates, theoretical bandwidth, and the perception of increased costs associated with increased bandwidth.

Commission Procedure

The respondent maintained, in its reply comments, that the Commission cannot unilaterally change the definition of universal service, but rather must follow the statutory procedures set forth in Section 254 of the Communications Act of 1934, as amended (the 'Act') which includes referral to the Joint Board on Universal Service."

RUS has frequently noted that the Joint Board, in recommending, and the Commission, in adopting a voice grade bandwidth of 500 to 4,000 Hz, went through a lengthy and exhaustive rulemaking process.[1] When it changed the definition of bandwidth to 300 to 3,000 Hz, however, the Commission did so on its own motion in the 1997 Fourth Order on Reconsideration.[2] RUS believed and continues to believe that such an important change merited public comment. If the respondent's procedural argument is correct, RUS would not object to a return to the originally adopted definition and referral of the matter to the Joint Board for consideration.

RUS Can Easily Demonstrate That Increased Bandwidth Will Improve Data Rates

The respondent maintained that RUS has not and can not demonstrate that an increase in bandwidth will improve data rates.

At the Proxy Model Workshops in the fall of 1997, months before the Commission redefined voice grade access, RUS advised the Commission that bandwidth alone, without stated tolerances or measures of dynamic range and noise, is an incomplete description of voice circuit quality.[3] We went on to say that a specific bandwidth, with other important measures unstated, would not guarantee improved data performance.[4]

This acknowledgement does not mean that bandwidth is unimportant. Not only did RUS state that bandwidth is only one important factor, we advised the Commission in the October 27 filing that they should move away from a simple bandwidth specification and focus on the connection to the network instead. We stated that switch components can be quickly changed but the local loop presents the most expensive and longest lasting part of the network, and thus the greatest long-term barrier to system improvements. Although we

1. *See, among others,* Exparte Comments of RUS, Jan. 30, 1998 (www.usda.gov/rus/unisrv/fc8_1_30xp.htm).

2. *See Fourth Order on Reconsideration,* CC Docket No. 96-4, Report and Order in CC Docket Nos. 96-45, 96-262, 94-1, 95-72, FCC 97-420 (rel. Dec. 30, 1997)

3. *See* Exparte Comments of RUS, October 27, 1997 (www.usda.gov/rus/unisrv/fc7_10_27xp.htm).

4. *Id*.

only discussed the local loop in our comments, this argument applies equally to any type of network connection.

How can RUS show that increased bandwidth means higher data rates? In the absence of other performance measures in the definition, we must assume that in a comparison, all other conditions are equal. Therefore, the question is: does a 3,100 Hz bandwidth (300 to 3,400 Hz) as we proposed, or a 3,500 Hz bandwidth (500 to 4,000Hz) as originally set, have more ability to carry information than a 2,700 Hz bandwidth (300 to 3,000 Hz)?

Shannon's Information Theorem unequivocally demonstrates that information-carrying capability is proportional to bandwidth.[5] Therefore, all else being equal, a bandwidth wider than 300 to 3,000 kilohertz will allow greater data rates.

Digital Switches Are Not Permanent Barriers to Achieving a Higher Frequency Response

The respondent introduced an Alliance for Telecommunications Industry Solutions (ATIS) Technical Report as evidence that the frequency response of a digital switch cannot be increased to 4,000 Hz practically through new techniques.[6]

In its filings on bandwidth, RUS has proposed a 300 to 3,400 Hz bandwidth, not a full 4,000 Hz bandwidth. RUS discussions of theoretical maximum frequency response have always been presented to show that bandwidth barriers in the switch may be temporary, while barriers in outside plant are long term. The current voice grade access definition encourages carriers to build modem data rate barriers in rural areas that will last 20 years or more, because of a switch limitation that could be overcome in a short time.

Nevertheless, the RUS statements about a higher theoretical switch bandwidth are accurate. To understand how it is possible to increase the operating bandwidth of a digital switch to its theoretical maximum requires some technical background.

To convert an analog signal to digital code and back again without alteration the signal must be sampled at a minimum of twice the highest frequency of interest. Also, if sampled at this minimum, there must be no frequency content above the highest frequency of interest. In the case of telephones, sampling is done at 8,000 Hz, so there can be no frequency content above 4,000 Hz at the time of conversion.

If there is any information above 4,000 Hz and it is not removed before sampling, it interacts with the sampling frequency and can be transformed into digital code that produces frequencies equal to the difference with the sampling frequency when decoded. For example, an unfiltered 7,000 Hz tone sampled at 8,000 Hz would result in a 1,000 Hz distortion artifact, and an unfiltered 7,500 Hz tone would result in a 500 Hz artifact.

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5. *See* Telecommunications Transmission Handbook, 3rd edition, Roger L. Freeman, at 823. Shannon's Theorem states: *Bitrate = Bandwidth times* $\log_2(1+\text{signal to noise ratio})$.

6. *See* the ATIS Technical Report No. 60 (*Unbundled Voicegrade Analog Loops*), July 1999, at 3.

Because the distortion artifact frequencies vary inversely with the frequencies contained in the original signal, this "aliasing" distortion is readily apparent to the listener.

One way of preventing aliasing is to remove these frequencies before the conversion through the use of an analog anti-aliasing filter. Because a perfect analog filter (that is, a filter which passes 4,000 Hz but not 4,001 Hz) is not realizable, anti-aliasing filtering must start at a point below 4000 Hz to make sure that nothing above 4,000 Hz passes through. As noted in the ATIS Technical Report, digital conversion typically constrains the top frequency to about 3,400 Hz and this is a result of the analog anti-aliasing filter.

While analog anti-aliasing filters are universal in current telephone digital switches, there in another well-understood method of analog-to-digital conversion, called *oversampling*, that minimizes the performance limitations of such filters.[7] Oversampling, which is not new, can be used both during analog-to-digital and digital-to-analog conversion.[8] It was first employed in digital recorders used for mastering consumer compact discs in the 1980s, and is found in even the least expensive personal compact disc players on the market today.

Oversampling operates by boosting the sampling rate in the converter to many multiples of the rate that will eventually be used for storage or transmission. For purposes of illustration, consider an analog-to-digital converter that instead of sampling at 8,000 Hz, samples at 128,000 Hz, a rate 16 times higher. With such a high sampling rate, there may be no need for an anti-aliasing filter because the original signal has no components above 64,000 Hz. If a filter is needed, it only needs to remove frequencies above 64,000 Hz, which means it can begin filtering far above 4,000 Hz.[9]

Once converted to digital code, the bandwidth can be reduced by <u>digital</u> filtering to 4,000 Hz with an 8,000 Hz sampling rate. Because nearly perfect digital filters <u>are</u> realizable, this allows the usable bandwidth to approach the theoretical maximum. An additional benefit is that digital filtering virtually eliminates other distortions of analog filters such as frequency dependent delay and "ringing" near the top frequency.

As a further illustration, the first digital recorders achieved about a 19,000 Hz top frequency because of the analog anti-aliasing filter. This is about 86% of the theoretical maximum of 22,050 Hz, quite similar to the performance of the telephone central office (3400 Hz is 85% of 4000 Hz). Newer recorders, through the use of oversampling and

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7. *See A Fundamental Introduction to the Compact Disc Player*, Grant Erickson, Department of Electrical Engineering, University of Minnesota, November 29, 1994, for a general explanation of oversampling and digital filtering. (www.amtechdisc.com/file/amtech/CDPAPER.HTML)

8. *See How Chesky Surmounted Digital Audio's Flaws*, Al Fasoldt, Copyright 1989, The Syracuse Newspapers. (twcny.rr.com/technofile/texts/chesky89.html)

9. In fact, only frequencies above 124,000 Hz must be eliminated because they are the only ones that can produce audible difference-frequency artifacts in the theoretical maximum bandwidth of the telephone, *i.e.*, approximately 0 Hz to 4,000 Hz.

digital filtering, are capable of a bandwidth with a top frequency of about 22,000 Hz, extremely close to the theoretical maximum. Thus, digital switches could pass frequencies at nearly the theoretical maximum of 4,000 Hz if inexpensive and widely used oversampling and digital filtering techniques were employed.

RUS is not advocating that voice grade access presume such a future step in switch evolution, but provides this discussion to demonstrate that the bandwidth barrier presented by the switch should not be viewed as a permanent and impenetrable roadblock. RUS loan feasibility studies default to an expected useful life of central office equipment of 12 years, and an expected useful life of copper loop plant of 20 years. Copper plant has been known to remain in service well over forty years. Switches are upgraded with software and hardware replacements several times during their useful lives, and any time line cards are replaced, oversampling and digital filtering could be added. Copper plant loops, on the other hand, are the more nearly permanent roadblock. The consequences of a lowered bandwidth definition of voice grade service is that the construction of new barriers to advanced services are being encouraged.

The ATIS Voice Grade Definition Draws Attention to the Reason for the RUS Approach

The explanatory footnote to the ATIS definition of *voiceband* states that "[t]he frequencies, approximately 300 Hz and approximately 3300 Hz, are based on cables with H88 loading scheme described in Section 5.2. If another loading scheme is used, e.g. D66, or if the plant is not loaded, the upper frequency of the voiceband is constrained by the anti-aliasing filter of the analog-to-digital conversion process to approximately 3,400 Hz."

The statement about the constraints imposed by the analog-to-digital conversion is merely a description of what is in place, not what is possible. ATIS made no attempt to cover theoretical maximums.

But this footnote does draw attention to the point RUS has made repeatedly. There are two primary limitations in the telephone circuit - those in the electronics, such as the digital switch and transmission equipment, and those of the facility connecting the customer to the network, such as the copper loop. Of these, RUS believes the network connection should be the focus of the definition of voice grade access because it is generally the most expensive and longest lasting part of the network.

Inductive loading, for example, is an impediment found in the loop. Loading is used on long loops to maintain good voice frequency response. Loading inserts inductors (copper coils) at intervals to tune the circuit so that it can carry a reduced range of frequencies for a longer distance. The H88 loading mentioned in the ATIS footnote is particularly harmful to data. The bandwidth restriction alone impairs operation of a 28-kilobit/second modem (28 K modems). Also, because noise increases with loop length and only long loops are loaded, loaded circuits typically have less dynamic range. This, too, reduces 28 K modem performance. Further, loading introduces frequency dependent delay, another factor that reduces modem performance. Finally, loading sacrifices all the frequencies above the

voiceband. These are the frequencies needed to carry Digital Subscriber Line (DSL) broadband services. This means that loading is not only a problem for 28 K modems, it is an absolute roadblock to advanced services.

Others have argued that RUS should not be concerned about conventional modem access because broadband will dominate in the future. However, as can be seen in the previous paragraph, the two subjects are strongly related. In general, loops capable of supporting a 28 K modem can also support DSL with the addition of suitable electronics.

As mentioned earlier, we advised the Commission in 1997 that the impairments caused by the connection to the network are more significant and longer lasting than those caused by central office electronics. The significance of loop impairments is particularly important in rural areas where the cost of cable plant dominates the cost of providing telephone service.

The wisdom of focusing on the network connection is even more evident when it is considered that DSL broadband avoids the bandwidth limitations of the digital switch entirely and goes directly from the loop to the Ethernet. The Commission has recognized the wisdom of focusing on the loop by eliminating loading as a design element in their Synthesis Cost Model. This was done deliberately so that the modeled plant would not inhibit access to advanced services such as DSL. We encourage the Commission to maintain that focus on the network connection and extend it as they consider changing the definition of voice grade access. If nothing else, the Commission should state the voice grade definition in engineering terms and describe <u>how</u> and <u>where</u> it is to be measured.

As new plant is built to unserved customers and as aging plant is replaced, it is critically important that this plant be ready to evolve to an advanced services capable design. Incentives to build new plant which provides lower quality service and includes impediments to advanced services would be inconsistent with the spirit of Section 706 of the Telecom Act. The RUS does not favor a policy that will promote the insertion of new barriers to broadband or that will lower the level of service supported <u>status quo ante</u> May 8, 1997.

<u>A Properly Crafted Bandwidth Definition Will Promote Great Increases in Data Rates</u>

It was suggested that it might not be possible to establish a technical specification that establishes a particular level of performance.

Technical specifications are established routinely in almost every industry for exactly this purpose, *i.e.*, to produce a particular level of performance. A 300 Hz to 3400 Hz bandwidth requirement, in conjunction with a 28 K modem requirement, will promote improved data rates. More important, plant that will support a 28 K modem will generally support DSL with the addition of suitable equipment, which allows rates 10 to 50 times higher than conventional modem access. As such, it will conform to the universal service principle in the Telecommunications Act's Section 254 (b) and (c) regarding access to advanced services.

An Expanded Bandwidth Requirement Need Not Result in Enormous New Expenses

It is not the intention of RUS either to require wasteful investment that produces no benefit or to eliminate support to those who fall under the line. To ensure that adequate support continues for existing plant that does not meet the prescribed universal service definition, RUS has proposed to grandfather that plant for a reasonable period of time, to be determined by the state regulatory commission.[10] If, at the end of the grandfathering period, a small number of remote rural subscribers cannot receive 28 K modem performance, only proportional reductions in support based upon those subscribers should be adopted (scaling).[11] While the RUS supported method of scaling is equitable, other allocation system exist that would promote high quality service without financially devastating results. In any case, no new impediments should be supported.

Universal service policies should focus on encouraging the deployment of plant which can evolve and provide consumers access to advanced services. What is prohibitively expensive is to build or replace plant with narrowband facilities, and later, discard these facilities and replace them with broadband infrastructure.

RUS has brought a similar focus on evolution in its implementation of an earlier expanded definition of service. In 1993, Congress charged the Agency with implementing State Telecommunications Modernization Plans.[12] Chief among the requirements of that legislation was that customers be able to receive 1 megabit/second data rates through their telephone lines. RUS implemented these requirements over a period of time and directed the requirements only at new plant to be constructed either in currently unserved areas or in system rebuilds. As was discussed in our original comments, the increased cost of building plant that is both 28 K modem and DSL capable is minimal when done during a necessary build. Investment in evolvable plant is forward-looking and prudent.

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10. *See* RUS Comments on Redefining Voice Grade Access, Jan. 19, 2000. (www.usda.gov/rus/unisrv/01-19com.htm)

11. If these mechanisms were in effect today, all RUS borrowers would continue to receive the same support they currently receive even without upgrading plant. Grandfathering should be imposed for a term sufficient to allow LECs the opportunity to replace plant in a logical manner, at least five years. Scaling would only come into play after the grandfathering period had ended, and then, support would only be lost for those specific customers that could not connect at 28.8 K. Even then, most RUS-financed LECs would lose little or no support because the majority of their customers can connect at 28.8 K now. As of the 1992 RUS Loop Survey, approximately two-thirds of all RUS-financed LEC customers were on short, nonleaded loops, which should pass 28.8 K in rural areas just as they do in urban areas. Many D66 loaded loops will pass a 28.8 K modem signal.

12. Rural Electrification Loan Restructuring Act, Pub. L. No. 103-129, 107 Stat. 1356, codified at 7 U.S.C. §935.

Conclusion

RUS comments concerning the definition of voice grade access focus on the future. The current definition focuses on the past. The definition of voice grade service will be a defacto standard for new plant. RUS believes the definition should promote the Act's promise of comparable service and rates in rural and non-rural areas and be capable of providing access to advanced services. Universal service support should not be utilized to construct new barriers to the broadband world of the future. This definition can set a high standard while accommodating existing systems and providers that can't currently meet the definition. The RUS recommendation promotes comparable service without wasteful investment. RUS appreciates the opportunity to provide clarifying comments.

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Christopher A. McLean
Acting Administrator
Rural Utilities Service

Date

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Gary B. Allan
Chief, Universal Services Branch
Advanced Services Division

Orren E. Cameron III, P.E.
Director
Advanced Services Division